Appendix C

Timber Properties

Timber properties include the timber's strength and grade. Timber remains an important material because it is readily available in much of the world. Also, it is relatively easy to work with when using common tools. As an organic material, the strength properties of timber are influenced by factors such as the species of the tree, the direction of a load, and the size and grade of the lumber. These factors are considered in *Tables C-1* through *C-7, pages C-3* through *C-11*. Other factors that could influence the strength of timber are not covered in this manual.

CIVILIAN-DESIGN STRESS

C-1. *Table C-1* lists recommended civilian-design stresses based on the species, the size, and the grade of the timber members. Use this table for all semipermanent and permanent designs. Use it anytime a significant safety factor is wanted or when conditions allow the accomplishment of the mission using these conservative stress values.

MILITARY-DESIGN STRESS

C-2. *Table C-2* lists allowable loads for expedient and temporary bridges based on timber sizes. Field experience has validated these higher stress values for temporary bridges that are not expected to have a heavy traffic load. Bridges designed or classified using these values should be watched closely for any signs of reduced carrying capacity. These bridges will have much higher maintenance requirements than those designed or classified with more conservative stress values. The data in *Table C-2* is based on the assumption that the beam and stringer members are of select structural grade. Do not use this table if there are any doubts about the grade of timber.

C-3. Any bridge that meets the criteria in *Table C-2* (but is of an unknown species of timber) can be classified based on the allowable stresses recommended in *paragraph 3-47*.

C-4. The allowable stresses depend on the direction of loading of the timber member. *Figure C-1, page C-11,* shows the radial, tangential, and longitudinal directions for the cross section of a log. The radial direction proceeds from what was the center of the tree out to the edge. The tangential direction is parallel (or tangent) to the growth rings of the tree at any particular point.

The longitudinal direction represents the direction of growth for the tree. For example, the longitudinal direction of a tree trunk is up and down. The longitudinal direction is said to be parallel to the grain. The radial and the tangential directions are perpendicular to the grain.

C-5. Another factor that influences the allowable stress is the grade of lumber. Grading of a particular species is done according to the rules of the agency responsible for inspecting commercial timber for that species. Select a structural grade timber that generally has no knots and very few other imperfections, which can reduce strength. Grade No. 1 has no knots, but has slightly more imperfections than select structural grades. Higher grade numbers allow a greater number of knots and imperfections. The higher the grade number the lower the timber quality.

C-6. The grades listed in *Table C-1, pages C-3* through *C-6,* are commercial grades common in the US. Timber members obtained through the AFCS should match one of these specifications. If using native timber, try to locate similar civilian specifications or use the values in *Chapter 3* for timbers of an unknown species. Another alternative is to compare a foreign species to a similar species listed in *Table C-1*. Such a comparison requires extensive experience to ensure that any crucial differences are not overlooked.

Table C-1. Properties of Structural Lumber (Visually Graded)

Commercial Grade	Size	Allowable Unit Stresses (psi)[1]						Modulus of Elasticity (E) (x 1,000)	Grading Agency
		Extreme Fiber in Bending (F_b)		Tension Parallel to the Grain (F_t)	Horizontal Shear (F_v)	Compression (Fc ⊥) Perpendicular to the Grain	Compression ($F_{c\parallel}$) Parallel to the Grain		
		Single-Member Use	Repetitive-Member Use						
Douglas Fir/Larch (Surfaced Dry or Green) (Maximum moisture content is 19 percent.)									
Dense select structural	2 to 4 inches thick and 2 to 4 inches wide	2,450	—	1,400	95	455	1,850	1,900	West Coast Lumber Inspection Bureau and Western Wood Products Association (notes 2 through 9)
Select structural		2,100	—	1,200	95	385	1,600	1,800	
Dense No. 1		2,050	—	1,200	95	455	1,450	1,900	
No. 1		1,750	—	1,050	95	385	1,250	1,800	
Dense No. 2		1,700	—	1,000	95	455	1,150	1,700	
No. 2		1,450	—	850	95	385	1,000	1,700	
No. 3		800	—	475	95	385	600	1,500	
Dense select structural	2 to 4 inches thick and 5 inches or wider	2,100	—	1,400	95	455	1,650	1,900	
Select structural		1,800	—	1,200	95	385	1,400	1,800	
Dense No. 1		1,800	—	1,200	95	455	1,450	1,900	
No. 1		1,500	—	1,000	95	385	1,250	1,800	
Dense No. 2		1,450	—	775	95	455	1,250	1,700	
No. 2		1,250	—	650	95	385	2,050	1,700	
No. 3		725	—	375	95	385	675	1,500	
Dense select structural	Beams and stringers	1,900	—	1,100	85	455	1,300	1,700	West Coast Lumber Inspection Bureau (notes 2 through 9)
Select structural		1,600	—	950	85	385	1,100	1,600	
Dense No. 1		1,550	—	775	85	455	1,100	1,700	
No. 1		1,200	—	825	85	385	1,000	1,600	
Dense select structural	Posts and timbers	1,750	—	1,150	85	455	1,350	1,700	
Select structural		1,500	—	1,000	85	385	1,150	1,600	
Dense No. 1		1,400	—	950	85	455	1,200	1,700	
No. 1		1,200	—	825	85	385	1,000	1,600	
Select dex	Decking	1,750	2,000	—	—	385	—	1,800	
Commercial dex		1,450	1,650	—	—	385	—	1,700	
Dense select structural	Beams and stringers	1,900	—	1,250	85	455	1,300	1,700	Western Wood Products Association (notes 2 through 9)
Select structural		1,600	—	1,050	85	385	1,100	1,600	
Dense No. 1		1,550	—	1,050	85	455	1,100	1,700	
No. 1		1,350	—	900	85	385	925	1,600	
Dense select structural	Posts and timbers	1,750	—	1,150	85	455	1,350	1,700	
Select structural		1,500	—	1,000	85	385	1,150	1,600	
Dense No. 1		1,400	—	950	85	455	1,200	1,700	
Select dex	Decking	—	2,000	—	—	—	—	1,800	
Commercial dex		—	1,650	—	—	—	—	1,700	
Select dex		—	2,150	—	Stresses apply at 15% moisture content			1,800	
Commercial dex		—	1,800	—	—	—	—	1,700	

Table C-1. Properties of Structural Lumber (Visually Graded) (continued)

Commercial Grade	Size	Allowable Unit Stresses (psi)[1]						Modulus of Elasticity (E) (x 1,000)	Grading Agency
		Extreme Fiber in Bending (F_b)		Tension Parallel to the Grain (F_t)	Horizontal Shear (F_v)	Compression (Fc ⊥) Perpendicular to the Grain	Compression (F_c‖) Parallel to the Grain		
		Single-Member Use	Repetitive-Member Use						
Hem-Fir (Surfaced Dry or Green) (Maximum moisture content is 19 percent.)									
Select structural	2 to 4 inches thick and 2 to 4 inches wide	1,650	—	975	75	245	1,300	1,500	West Coast Lumber Inspection Bureau and Western Wood Products Association (notes 2 through 9)
No. 1		1,400	—	825	75	245	1,050	1,500	
No. 2		1,150	—	675	75	245	825	1,400	
No. 3		650	—	375	75	245	500	1,200	
Select structural	2 to 4 inches thick and 5 inches or wider	1,400		950	75	145	1,150	1,500	
No. 1		1,200	—	800	75	245	1,060	1.500	
No. 2		1,000	—	525	75	245	875	1,400	
No. 3		575	—	300	75	245	550	1,200	
Select structural	Beams and stringers	1,300	—	750	70	245	925	1,300	West Coast Lumber Inspection Bureau (notes 2 through 9)
No. 1		1,050	—	525	70	245	750	1,300	
Select structural	Posts and timbers	1,200	—	800	70	245	975	1,300	
No. 1		975	—	650	70	245	850	1,300	
Select dex	Decking	1,400	1,600	—	—	245	—	1,500	
Commercial dex		1,150	1,350	—	—	245	—	1,400	
Select structural	Beams and stringers	1,250	—	850	70	245	925	1,300	Western Wood Products Association (notes 2 through 9)
No. 1		1,050	—	725	70	245	775	1,300	
Select structural	Posts and timbers	1,200	—	800	70	245	975	1,300	
No. 1		950	—	650	70	245	850	1,300	
Select dex	Decking	—	1,600	—	—	—	—	1,500	
Commercial dex		—	1,350	—	—	—	—	1,400	
Select dex		—	1,700	—	Stresses apply at 15% moisture content.			1,600	
Commercial dex		—	1,450	—	—	—	—	1,400	

Table C-1. Properties of Structural Lumber (Visually Graded) (continued)

Commercial Grade	Size	Allowable Unit Stresses (psi)[1]						Modulus of Elasticity (E) (x 1,000)	Grading Agency
		Extreme Fiber in Bending (F_b)		Tension Parallel to the Grain (F_t)	Horizontal Shear (F_v)	Compression (Fc ⊥) Perpendicular to the Grain	Compression ($F_{c\parallel}$) Parallel to the Grain		
		Single-Member Use	Repetitive-Member Use						
Hem-Fir (Surfaced Dry or Green) (Maximum moisture content is 19 percent.) (continued)									
Select structural	2 to 4 inches thick and 2 to 4 inches wide	2,000	—	1,150	100	405	1,550	1,700	Southern Pine Inspection Bureau (notes 2 through 9)
Dense select structural		2,350	—	1,350	100	475	1,800	1,800	
No. 1		1,700	—	1,000	100	405	1,250	1,700	
Dense No. 1		2,000	—	1,150	100	475	1,450	1,800	
No. 2		1,400	—	825	90	405	975	1,600	
Dense No. 2		1,650	—	975	90	475	1,150	1,600	
No. 3		775	—	450	90	405	575	1,400	
Dense No. 3		925	—	525	90	475	675	1,500	
Select structural	2 to 4 inches thick and 5 inches or wider	1,750	—	1,150	90	405	1,350	1,700	
Dense select structural		2,050	—	1,300	90	475	1,600	1,800	
No. 1		1,450	—	975	90	405	1,250	1,700	
Dense No. 1		1,700	—	1,150	90	475	1,450	1,800	
No. 2		1,200	—	625	90	405	1,000	1,600	
Dense No. 2		1,400	—	725	90	475	1,200	1,600	
No. 3		700	—	350	90	405	625	1,400	
Dense No. 3		825	—	425	90	475	725	1,500	
No. 1	5 inches or thicker	1,350	—	875	110	270	775	1,500	
Dense No. 1		1,550	—	1,050	110	315	925	1,600	
No. 2		1,100	—	725	95	270	625	1,400	
Dense No. 2		1,250	—	850	95	315	725	1,400	
Dense standard dex	Decking (2½ to 4 inches thick)	—	1,800	—	—	—	—	1,600	
Select dex		—	1,300	—	—	—	—	1,400	
Dense select dex	Decking (2 inches or wider)	—	1,500	—	—	—	—	1,400	
Commercial dex		—	1,300	—	—	—	—	1,400	
Dense commercial dex	Decking	—	1,500	—	—	—	—	1,400	

NOTES:

1. The allowable unit stresses shown are for selected species and commercial grades. For stresses of other species and commercial grades not shown, the designer is referred to the grading rules of the appropriate grading agency or the National Design Specification for Wood Construction (NDS).

2. The recommended design values given are applicable to lumber that will be used under dry conditions such as in most covered structures. For 2- to 4-inch-thick lumber, the surfaced-dry size should be used. In calculating design values, the natural gain in strength and stiffness that occurs as lumber dries has been taken into consideration as well as the reduction in size that occurs when unseasoned lumber shrinks. The gain in load-carrying capacity due to increased strength and stiffness resulting from drying more than offsets the design effect of size reduction due to shrinkage. For 5-inch and thicker lumber, the surfaced sizes also may be used because design values have been adjusted to compensate for any loss in size by shrinkage, which may occur.

3. Tabulated tension-parallel-to-the-grain values are for all species cut to a width of 5 inches or wider. The 2- to 4-inch-thick size classification applies to 5- and 6-inch widths only for grades of select structural No. 1 through 3 (including dense grades). For lumber wider than 6 inches in these grades, the tabulated F_t values should be multiplied by the following factors:

Grade	Multiply F_t by Appropriate Factor Below		
	5 and 6 Inches Wide	8 Inches Wide	10 Inches and Wider
2 to 4 inches thick and 5 inches or wider (including dense grades)	1.00	0.90	0.80
Select structural No. 1, 2, and 3	1.00	0.80	0.60

Table C-1. Properties of Structural Lumber (Visually Graded) (continued)

4. The values in the table are based on edgewise use. For thicknesses of 2 to 4 inches, when used flatwise, the recommended design values for fiber stress in bending may be multiplied by the following factors:

Width	Thickness		
	2 Inches	3 Inches	4 Inches
2 to 4 inches	1.10	1.04	1.00
5 inches or wider	1.22	1.16	1.11

5. When 2- to 4-inch-thick lumber is manufactured at a maximum moisture content of 15 percent and used in a condition where the moisture content does not exceed 15 percent, the design values given in the table may be multiplied by the following factors (for southern pine, use tabulated design values without adjustment):

Extreme Fiber in Bending (F_b)	Tension Parallel to the Grain (F_t)	Horizontal Shear (F_v)	Compression Perpendicular to the Grain ($F_{c\perp}$)	Compression Parallel to the Grain ($F_{c\parallel}$)	Modulus of Elasticity (E)
1.08	1.08	1.05	1.00	1.17	1.05

6. When 2- to 4-inch-thick lumber is designed for use where the moisture content will exceed 19 percent for an extended period, multiply the design values by the factors given in the following table:

Species	Extreme Fiber in Bending (F_b)	Tension Parallel to the Grain (F_t)	Horizontal Shear (F_v)	Compression Perpendicular to the Grain ($F_{c\perp}$)	Compression Parallel to the Grain ($F_{c\parallel}$)	Modulus of Elasticity (E)
Douglas fir, larch, and hem-fir	0.86	0.84	0.97	0.67	0.70	0.97
Southern pine (2 to 4 inches thick, 5 inches or wider)	0.80	0.80	0.95	0.67	0.66	0.83

7. When lumber 5 inches and thicker is designed for use where the moisture content will exceed 19 percent for an extended period, multiply the values in the table (except those for southern pine) by the following factors:

Extreme Fiber in Bending (F_b)	Tension Parallel to the Grain (F_t)	Horizontal Shear (F_v)	Compression Perpendicular to the Grain ($F_{c\perp}$)	Compression Parallel to the Grain ($F_{c\parallel}$)	Modulus of Elasticity (E)
1.00	1.00	1.00	0.67	0.91	1.00

8. When lumber 4 inches and thinner is manufactured unseasoned, multiply the tabulated values by a factor of 0.92 (except southern pine).

9. Stress-rated boards of nominal thickness (1, 1 1/4, and 1 1/2 inch) and wider dimensions of most species are permitted the recommended design values given for select structural No. 1 through 3 grades as shown for 2- to 4-inch-thick categories when graded according to the stress-board provisions applicable grading rules. Information on stress-rated board grades applicable to the various species is available from the respective grading standards.

Table C-2. Properties of Timber Stringers

Nominal Size (in)	Moment Capacity (m) (kip-feet)[1]	Shear Capacity (v) (kips)[2]	Maximum Span Length (L) (ft)[3]	Nominal Size (in)	Moment Capacity (m) (kip-feet)[1]	Shear Capacity (v) (kips)[2]	Maximum Span Length (L) (ft)[3]
4x8	8.53	3.20	9.50	12x20	160.00	24.00	23.80
4x10*	13.33	4.00	11.90	12x22	193.60	26.40	26.20
4x12*	19.20	4.80	14.30	12x24	230.00	28.80	28.60
6x8	12.80	4.80	79.50	14x14	91.50	19.60	16.70
6x10	20.00	6.00	11.90	14x16	119.50	22.40	19.10
6x12	28.80	7.20	14.30	14x18	151.20	25.20	21.50
6x14*	39.20	8.40	16.70	14x20	186.70	28.00	23.80
6x16*	51.20	9.60	19.10	14x22	226.00	30.80	26.20
6x18*	64.80	10.80	21.50	14x24	269.00	33.60	28.60
8x8	17.07	6.40	79.50	16x16	136.50	25.60	19.10
8x10	26.70	8.00	11.90	16x18	172.80	28.80	21.50
8x12	38.40	9.60	14.30	16x20	213.00	32.00	23.80
8x14	52.30	11.20	16.70	16x22	258.00	35.20	26.20
8x16	68.30	12.80	19.10	16x24	307.00	38.40	28.60
8x18*	86.40	14.40	21.50	18x18	194.40	32.40	21.50
8x20*	106.70	16.40	23.80	18x20	240.00	36.00	23.80
8x22*	129.10	17.60	26.20	18x22	290.00	39.60	26.20
8x24*	153.60	19.20	28.60	18x24	346.00	43.20	28.60
10x10	33.30	10.00	11.90	8θ	10.05	5.70	9.50
10x12	48.00	12.00	14.30	9θ	14.31	7.20	10.70
10x14	65.30	14.00	16.70	10θ	19.63	8.80	11.90
10x16	85.30	16.00	19.10	11θ	26.10	10.60	13.10
10x18	108.00	18.00	21.50	12θ	33.90	12.70	14.30
10x20	133.30	20.00	23.80	13θ	43.10	15.00	15.50
10x22*	161.30	22.00	26.20	14θ	53.90	17.40	16.70
10x24*	192.00	24.00	28.60	16θ	80.40	22.60	19.10
12x12	57.60	14.40	14.30	18θ	114.50	28.60	21.50
12x14	78.40	16.80	16.70	20θ	157.10	35.40	23.80
12x16	102.40	19.20	19.10	22θ	209.00	42.70	26.20
12x18	129.60	21.60	21.50	24θ	271.00	50.80	28.60

NOTES:

1. To determine the moment capacity for a stringer not listed, compute as follows:

Rectangular: $m = \frac{bd^2}{30}$

Round: $m = 0.02D^3$

2. To determine the shear capacity for a stringer not listed, compute as follows:

Rectangular: $v = \frac{bd}{10}$

Round: $v = 0.09D^2$

3. To determine the maximum length for a stringer not listed, compute as follows:

$L = 1.19d$

where—

b = stringer width, in inches
d = stringer depth, in inches
D = diameter
L = maximum span length
m = moment capacity
v = shear capacity

** Lateral bracing required at midspan and span ends.*

Table C-3. Post and Pile Data

Post Size (in)	Post Capacity (kips)[1]	Maximum Height (ft)	Pile Size (in)	Pile Capacity (kips)[2]	Maximum Height (ft)
6x6	18	15	8	25	18
6x8	24	15	9	32	20
8x8	32	20	10	47	25
8x10	40	20	11	47	25
10x10	50	25	12	56	27
10x12	60	25	13	66	29
12x12	72	30	14	76	31

NOTES:

1. For posts not listed, compute as follows:

$\frac{cap}{post} = 0.5A_p$ (A_p = bd, in inches^2)

maximum height = 30b (b in feet)

where—

A_p = *plate area, in inches*
b = *beam width*
d = *stringer depth*

2. For piles not listed, compute as follows:

$\frac{cap}{pile} = 0.39D^2$ (*D in inches*)

maximum height = 27D (D in feet)

where—

D = *pile diameter*

Table C-4. Properties of Rectangular Beams

Width (in)	Depth (in)									
	6	8	10	12	14	16	18	20	22	24
4	24	43	67	96	131	171	216	267	323	384
	16	21	27	32	37	43	48	53	59	64
6	36	64	100	144	196	256	324	400	484	576
	24	32	40	48	56	64	72	80	88	96
8	48	85	133	192	261	341	432	533	645	768
	32	43	53	64	75	85	96	107	117	128
10	60	107	167	240	327	427	540	667	807	960
	40	53	67	80	93	107	120	133	147	160
12	72	128	200	288	392	512	648	800	968	1,152
	48	64	80	96	112	128	144	160	176	192
14	84	149	233	336	457	597	756	933	1,129	1,344
	56	75	93	112	131	149	168	187	205	224
16	96	171	267	384	523	683	864	1,067	1,291	1,536
	64	85	107	128	149	171	192	213	235	256
18	108	192	300	432	588	768	972	1,200	1,452	1,728
	72	96	120	144	168	192	216	240	264	288

NOTES:

1. The top number is the section modulus.

$S = \frac{bd^2}{6}$ **in cubic inches**

2. The bottom number is the effective shear area.

$A_v = \frac{2}{3}bd$ **in square inches**

where—

S = section modulus of the member

b = beam width

d = beam depth

A_v ***= effective shear area of the stringer***

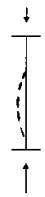
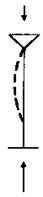
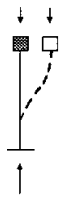
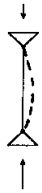
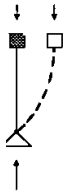
Table C-5. Properties of Round Beams

	Diameter (D) (in)													
	6	7	8	9	10	11	12	13	14	16	18	20	22	24
Section modulus (S): $S = \frac{\pi D^3}{32}$	21.00	34.00	50.00	72.00	98.00	131.00	170.00	216.00	270.00	402.00	572.00	785.00	1,045.00	1,358.00
Effective shear area (A_v): $A_v = \frac{3\pi D^2}{16}$	21.00	29.00	38.00	48.00	59.00	71.00	85.00	100.00	116.00	151.00	191.00	236.00	285.00	359.00
Area (A) (in^2): $A = \frac{\pi D^2}{4}$	28.30	38.50	50.30	63.60	78.50	95.00	113.00	132.70	153.90	201.10	254.50	314.20	380.10	452.40
Area (ft^2): $A = \frac{\pi D^2}{4}$	0.20	0.27	0.35	0.44	0.55	0.66	0.79	0.92	1.07	1.40	1.77	2.18	2.65	3.14

Table C-6. Timber Weights and Specific Gravities

Species	Weight (lb per ft^3)	Specific Gravity
Ash (white and red)	40	0.62 to 0.65
Cedar (white and red)	22	0.32 to 0.38
Chestnut	41	0.66
Cypress	30	0.48
Elm (white)	45	0.72
Fir (Douglas spruce)	32	0.51
Fir (eastern)	25	0.40
Hemlock	29	0.42 to 0.52
Hickory	49	0.74 to 0.84
Locust	46	0.73
Maple (hard)	43	0.68
Maple (white)	33	0.53
Oak (chestnut)	54	0.86
Oak (live)	59	0.95
Oak (red and black)	41	0.65
Oak (white)	46	0.74
Pine (Oregon)	32	0.51
Pine (red)	30	0.48
Pine (white)	26	0.41
Pine (yellow, long-leaf)	44	0.70
Pine (yellow, short-leaf)	38	0.61
Poplar	30	0.48
Redwood (California)	26	0.42
Spruce (white and black)	27	0.40 to 0.46
Walnut (black)	38	0.61
Walnut (white)	26	0.41

Table C-7. Effective Length Factors for Columns

	(a)	(b)	(c)	(d)	(e)	(f)
Column shape (buckled shape shown by dashed line)						
Effective length factor (K) (theoretical value)	0.50	0.70	1.00	1.00	2.00	2.00
Design value of K*	0.65	0.80	1.20	1.00	2.10	2.00
End-condition code		Rotation fixed, translation fixed Rotation free, translation fixed Rotation fixed, translation free Rotation free, translation free				

***When ideal conditions are approximate. For riveted and bolted truss members (partially restrained), *K = 0.75*. For pinned connections in truss members, *K = 0.875* (pin friction).**

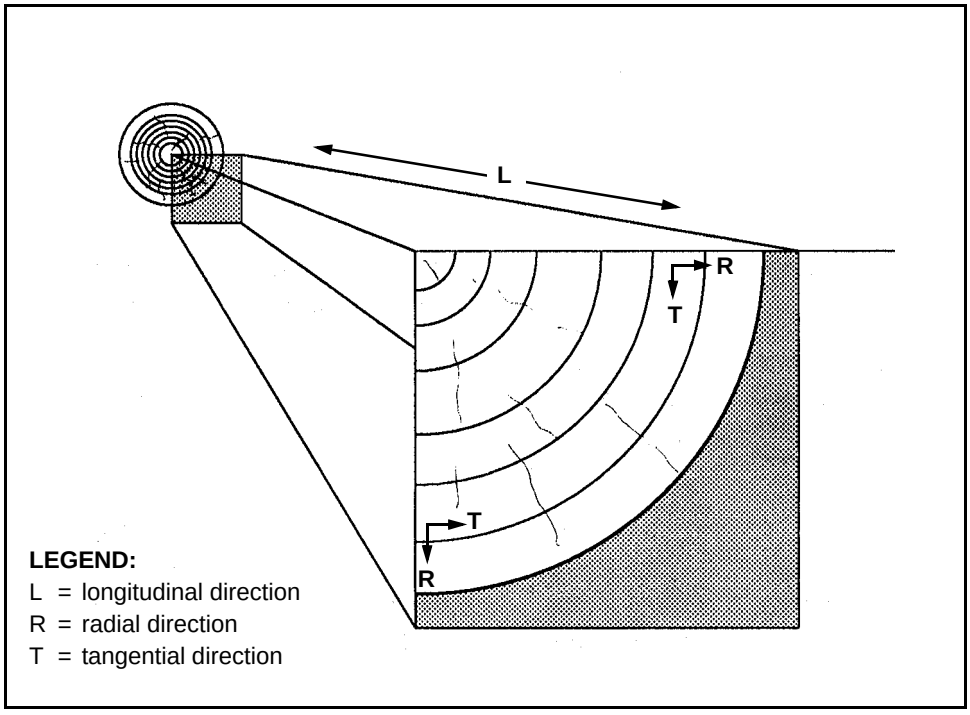


Figure C-1. Log Cross Section